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A TENTATIVE FIRE-DANGER METER FOR THE LONGLEAF-SLASH PINE TYPE

by

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The Occasional Papers of the Southern Forest Experiment Station present information on current Southern forestry problems under investigation at the Station. In some cases these contributions were first presented as addresses to a limited group of people, and as "occasional papers" they can reach a much wider audience. In other cases, they are summaries of investigations prepared especially to give a report of the progress made in a particular field of research. In any case, the statements herein contained should be considered subject to correction or modification as further data are obtained.

A TENTATIVE FIRE-DANGER METER FOR THE LONGLEAF-SLASH PINE TYPE

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A review of the larger fires in the South shows that many were not controlled while still small through failure to recognize the existing degree of fire danger. Ability to recognize dangerous fire conditions will not prevent fires from starting and spreading, but if the dispatcher can recognize dangerous conditions when they occur, he is in a better position to cope with these extreme conditions than otherwise. The size of a fire indicates not only the seriousness of fire conditions; it indicates also the promptness and effectiveness of the detection, dispatching, and suppression forces. Many fires that have been controlled during extremely hazardous conditions by use of adequate suppression forces and equipment, were potentially larger fires than some of those that "got away". Many fires on record, however, were over-manned. Overmanning may still be considered reasonable, as long as there are not more than about twice as many men as are needed; but when three and four times as many men are dispatched as are needed, the cost is excessive. The current rating of forest-fire danger can increase fire-control efficiency through reduction in the number of fires either under- or over-manned.

Fire-danger meters estimate by mechanical means the probable behavior of forest fires, as defined by the more significant variable elements of fire danger.1/ The longleaf-slash pine meter arbitrarily divides the range of values into classes of more or less uniform fire behavior. These classes are fixed to guide fire-control action, in presuppression and suppression. During days falling in the lowest danger class, only the year-long personnel are needed in the presuppression organization. As the conditions become more dangerous and the higher danger classes are reached, more and more of the temporary forces are assembled, until, in the highest danger class, every lookout station is manned, and all guards and patrolmen are on duty. At the same time, as the higher danger classes are reached, more men are required to control an individual fire, and there is a greater necessity for rapid and efficient detection and control.

1/ In the glossary of terms used in forest-fire control issued by the Forest Service in April 1939, "fire danger" is defined as "a general term expressing the sum total of both the constant and the variable factors which determine whether fires will start, spread, and do damage and that determine their difficulty of control. (Constant factors include values at stake, normal occurrence, fuel type, slope, aspect, soil type, etc. Variable factors include lightning, incendiary epidemics, illegal burning, inflammability, wind velocity, etc.)."

Fire danger in the longleaf-slash pine type changes rapidly and frequently. There is no long dry period or "fire season". Rather, there are short periods of high danger interspersed with periods of low danger, caused by rain or unsettled weather.

The fire-danger meter for the longleaf-slash pine type might be called more properly a meter for a predominantly herbaceous fuel type. This meter which has been called a longleaf-slash pine meter, to conform with the nomenclature of fuel-type mapping, is designed to be used where a herbaceous fuel largely determines the highest fire danger for the protected area.

A study of rate of spread of fire in the longleaf-slash pine type has been used as a basis for this tentative danger meter. Only four of the factors measured in analyzing the rate of spread were significant, namely, wind velocity, moisture content of fuel, fuel density, and age of "rough". An estimate of the rate-of-spread index,2/ based on these four factors would be of only limited value to a control organization, because (a) it would require an accurate map of fuel density and age of rough (which at times would need daily revisions), and also (b) it would require that the detection force locate the fire to the nearest acre. Furthermore, since omission of fuel density and age of rough lowered the correlation coefficient from 0.79 only to 0.75, it was decided to drop these variables, and a new analysis of rate of spread was made for the danger meter using only wind velocity and moisture content of fuel.

There are two main points to consider before using the rate of spread index for rating fire danger: Will it be possible to divide the rate of spread indices into fire-danger classes useful in guiding fire control?; and How can measurements taken at a central point be substituted for measurements of wind velocity and moisture content of fuel at the scene of a fire?

Division into danger classes is used to indicate changes in administrative action. The lower limit of the highest class should be fixed so that the highest class includes only emergency conditions. This class was determined by getting estimates of the actual increases in perimeter during a relatively small number of the worst fires that have occurred in the longleaf-slash pine type; from these data, the lower limit of the most

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2/ Rate of spread index is $\underline{b}$ in the formula for estimating the perimeter:

$$P = 0.26\, t^b$$

where $\underline{P}$ = total perimeter in chains;
$\underline{t}$ = total time in minutes from start of fire; and
$\underline{b}$ = a variable determined from rate of spread study, correlated with all significant factors except time.

The rate of spread, which is obviously the first derivative of the perimeter in respect to time (since it is the velocity at which the perimeter increases), $= \frac{dP}{dt} = (0.26)\,(b)\,(t^{b-1})$

hazardous class was estimated[3] to be at the rate-of-spread index 2.0.

The upper limit of the lowest class is set at the rate-of-spread index 0.8, which is obtained when there is no wind and the moisture content of the fuel is 40 percent. With a wind velocity of 1 mile an hour, it is necessary to have a moisture content of at least 56 percent to keep the index figure at 0.8 or less. With increasing wind, the moisture content of the fuel must get progressively higher to keep the index figure at or below 0.8. When these conditions prevail, fires cannot start with ordinary firebrands; this means that no administrative presuppression action is necessary.

In the absence of an adequate basis for defining the limits of the other danger classes, it was decided to make the class intervals equal in terms of rate-of-spread index. These class divisions may have to be modified, when more data are available.

The measurement of wind velocity and moisture content of fuel at a central point instead of at the scene of the fire will reduce the accuracy of danger estimates. If conditions at the central point represent worse than average conditions for the protection unit, however, the danger meter will not underestimate fire danger for the entire unit and also it probably will give a good estimate of the worst conditions.

To make it possible to determine fire-danger ratings quickly and easily, fuel moisture indicators[4] are used instead of fuel samples, which would have to be oven-dried before the moisture content could be found. In the rate-of-spread studies, the anemometer height is $3\frac{1}{2}$ ft., but to reduce the chances of the anemometer being molested and to conform with the height adopted as standard by the Appalachian Station, it was decided to change the height from $3\frac{1}{2}$ to $7\frac{1}{2}$ ft.

In correlating paired observations of actual moisture in the fuel with that registered by the indicators, the condition of the herbaceous vegetation was found to be a factor which affected the accuracy of the estimate. Separate analyses, therefore, were made for green, transitional, and cured herbaceous vegetation; and the values determined in these correlations were substituted for the fuel-moisture values in the equation for rate-of-spread index. The next step was to correlate paired observations of wind velocity at $3\frac{1}{2}$ ft. with the wind velocity at $7\frac{1}{2}$ ft. These values were substituted in the three equations previously derived.

The result is a set of three equations with the two independent variables, wind velocity and moisture content of an indicator, and

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3/ Since $P = 0.26\ t^b$,

$$\log P = \log 0.26 + b \log t$$

$$b = \frac{\log P - \log 0.26}{\log t}$$

4/ The fuel-moisture indicator to use with this danger meter is a set of three basswood slats prepared and issued by the Appalachian Forest Experiment Station. When the indicator is weighed on a special balance, the moisture content is read directly from the scale.

rate-of-spread index (and hence danger class) as the dependent variable.

From these formulae then the forest fire danger meter for the longleaf-slash pine type has been prepared as a slide rule. Detailed instructions for its use are issued to each fire-danger station set up. Briefly, these instructions are as follows: The scale for the prevailing herbaceous vegetation condition is used; the others are concealed by the face of the slide rule to prevent use of the wrong scale. At definite times each day, the wind velocity is determined and the fuel-moisture indicator is weighed on the special balance. To obtain the current fire-danger ratings, set the movable slide so that these measurements coincide; the arrow then shows the danger class and the rate-of-spread index. (It should be noted here that at any time during a rain the danger rating is class 1.)

No instructions or plans for administrative action are included with the danger meter at present, but without special instructions this meter should be useful as an aid in planning fire control. As one proceeds from class 1 (the lowest danger class, in which there is no need for manning towers) to class 5, the detection and suppression forces must be increased progressively. Although the danger meter does not include any direct measure of risk of fires starting, it may be possible to use it as an indicator of risk. For instance, incendiary fires usually will not be set when the danger rating is 1 or 2. A few will be set in days of class 3, but most will occur in days of class 4 and 5. No (or few) fires will be caused by carelessness with matches on days in danger class 1, but a few may be caused in days of class 2; and when the rating gets to be 3, 4, and 5, the likelihood of fires starting and spreading will increase.

When this tentative meter is checked, it is proposed to show the actual occurrence of fires, classified according to cause and final size on days in the various danger classes. Since the records kept will indicate rate-of-spread index, it is hoped that it will be possible to readjust the limits of the danger classes so that a definite percentage of the total number of fires may be expected to occur in days in each danger class. Also, if this meter proves satisfactory, it will be possible to state the average size of fire, and the average suppression force needed on days in each of the danger classes.

Although this danger meter is designed to measure fire danger at the time the wind and moisture readings are taken, it should be usable to predict fire danger for the next hour or day, by predicting what the wind and moisture conditions will be. Analysis of data taken at danger stations may show significant daily trends. Also examination of the Weather Bureau forecasts and local weather records may indicate for a given locality a method of forecasting the fire-danger rating.

This longleaf-slash pine fire danger meter is to be tested by the national forest protection units throughout the longleaf-slash pine type in the winter of 1939-1940. After it is used during this one fire season, it will be revised to improve its usefulness and accuracy if a revision seems warranted.

CUTTING AND PASTING INSTRUCTIONS

If desired, a working slide rule danger meter may be made from the figure on the last page as follows:

1. Cut off bottom block along heavy lines surrounding the moisture content scale for vegetation cured.

2. Mount the rest of the figure on light-weight, stiff cardboard.

3. Cut out the other three blocks along the heavy lines.

4. Cut out the window in the blank space of the title block between wind velocity and rate-of-spread index outlined by the light lines.

5. Paste the bottom block (showing moisture content scale for vegetation cured) on the other side of the cardboard on which is mounted the other moisture content scales.

6. Assemble as a slide rule by putting the moisture content scales in the middle; the two outside pieces are placed so that the printing faces out and the thumb openings coincide. Finally, bind the two long edges with 1/2" gum cloth mending tape.

Note: Assistance in the preparation of these materials was furnished by the personnel of Work Projects Administration Official Project 65-2-64-74.

LONGLEAF-SLASH PINE FIRE-DANGER METER

BEAUFORT SCALE	CALM	VERY LIGHT	LIGHT	GENTLE	MODERATE

WIND VELOCITY M.P.H. AT 7½ FEET: 0 5 10 15

RATE-OF-SPREAD INDEX: 0.5 1.0 1.5 2.0

1	2	3	4	5

FIRE-DANGER CLASS

DIRECTIONS: SET MEASURED MOISTURE CONTENT OF THE INDICATOR TO COINCIDE WITH MEASURED WIND VELOCITY; THE ARROW POINTS TO CURRENT DANGER RATING

ESTIMATED PERIMETERS AND RATES OF SPREAD FOR FIRES BURNING IN GRASS WITH NO BARRIERS 30 MINUTES AFTER DISCOVERY

FIRE-DANGER RATING	1		2		3		4	5
RATE-OF-SPREAD INDEX	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2
PERIMETER IN CHAINS	5	10	20	41	84	176	355	733
RATE-OF-SPREAD IN CHAINS OF PERIMETER PER MINUTE	0.1	0.3	0.6	1.5	3.6	8.4	19.2	43.3

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DANGER ↑ RATING

0 10 20 30 40 50 60 70 PERCENT MOISTURE, BASSWOOD INDICATOR

USE ONLY WHEN FUEL IS GREEN

0 10 20 30 40 50 60 70 PERCENT MOISTURE, BASSWOOD INDICATOR

DANGER ↓ RATING

USE ONLY WHEN FUEL IS IN TRANSITION STAGE

0 10 20 30 40 50 60 70 PERCENT MOISTURE, BASSWOOD INDICATOR

DANGER ↓ RATING

USE ONLY WHEN FUEL IS CURED